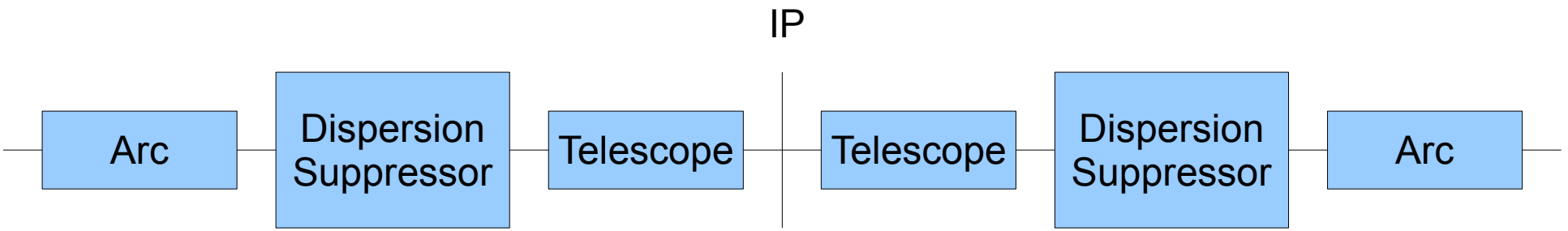
Challenges of RHIC lattice

S. Tepikian, March 13, 2009

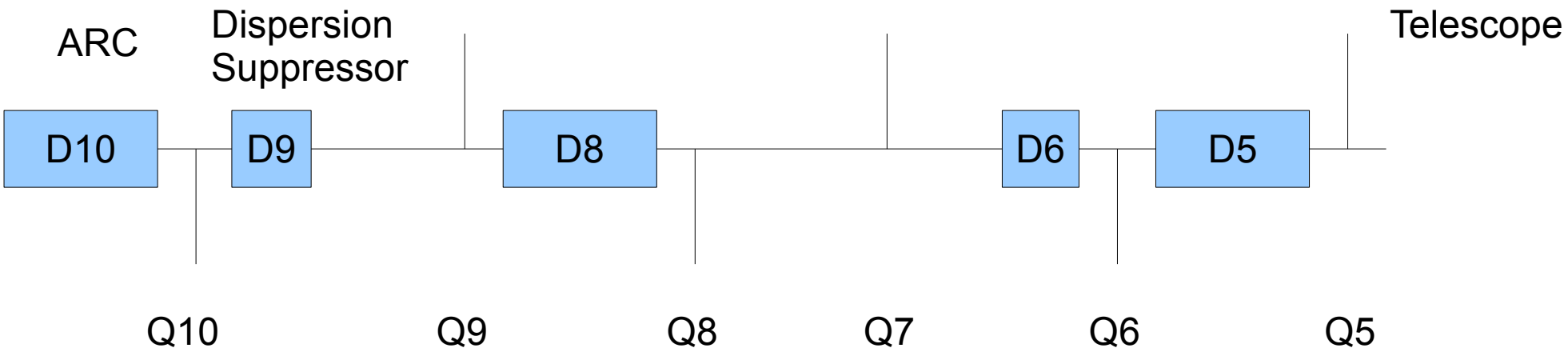
- Designing the Optics
  - Dispersion suppression and the ring geometry
  - Putting it all together
- Reducing the β*
  - Power supply restrictions
- IBS-suppression optics
- eCooling IR design
- pp2pp optics
- eRHIC IR design

RHIC IR



- Design the dispersion suppressors first
  - Use shortened and/or missing magnets in FODO cells
  - Determines the geometry of the ring
    - May be necessary if designing for an existing tunnel
  - For anti-symmetric optics, the suppressor must work for DOFO cells as well

RHIC IR

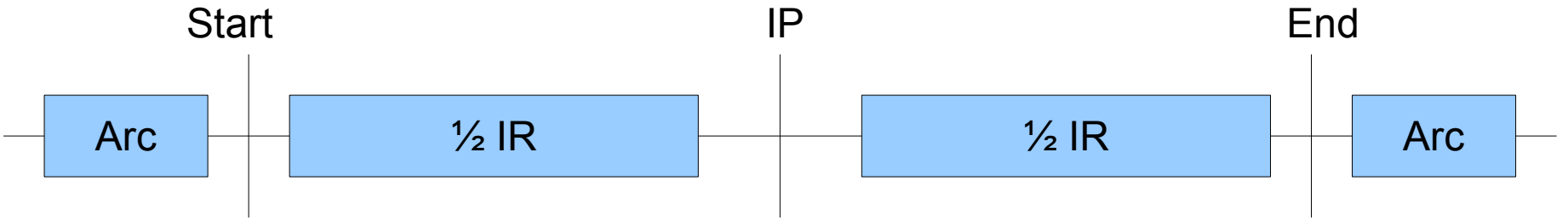


- The RHIC dispersion suppressor
  - Two short dipoles and an ARC dipole
- Varying the dipole lengths/positions changes the dispersion with negligible effect on the twiss functions.
- Drift spaces for: Injection kickers, septum, snakes, etc.

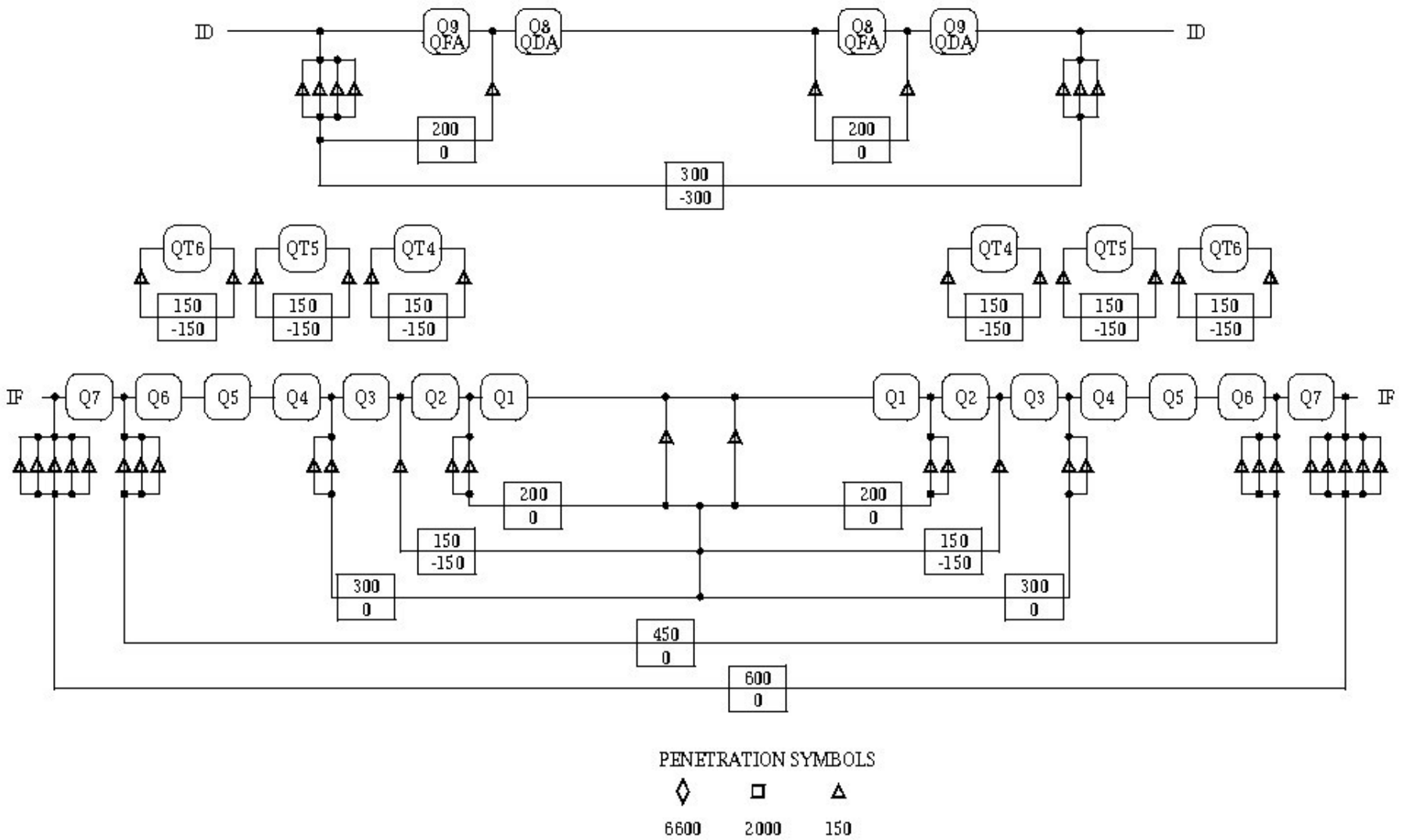
RHIC IR

- The telescope typically consists of a doublet and a triplet
  - Used to change the β* to small (or large) values
- The arcs are standard FODO cells with bending magnets
- Large warm drift space for: Rotators, Instrumentation, RF cavities, Beam dump, etc.

RHIC IR



- After fixing the geometry, only change the quadrupoles to adjust β*
- Treat the IR as a beam line
  - Use **Start** with the arc twiss parameters
  - Constrain **IP** to be the β*s of choice (6 constraints)
  - Constrain **End** to match to the Arc (6 constraints)
  - Additional constraints: β_{max}, machine tunes, etc.
- Fit to within the power supply limits.


ID
Q9 QFA
Q8 QDA
Q8 QFA
Q9 QDA
ID
200
0
200
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300
-300
QT6
QT5
QT4
QT4
QT5
QT6
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-150
150
-150
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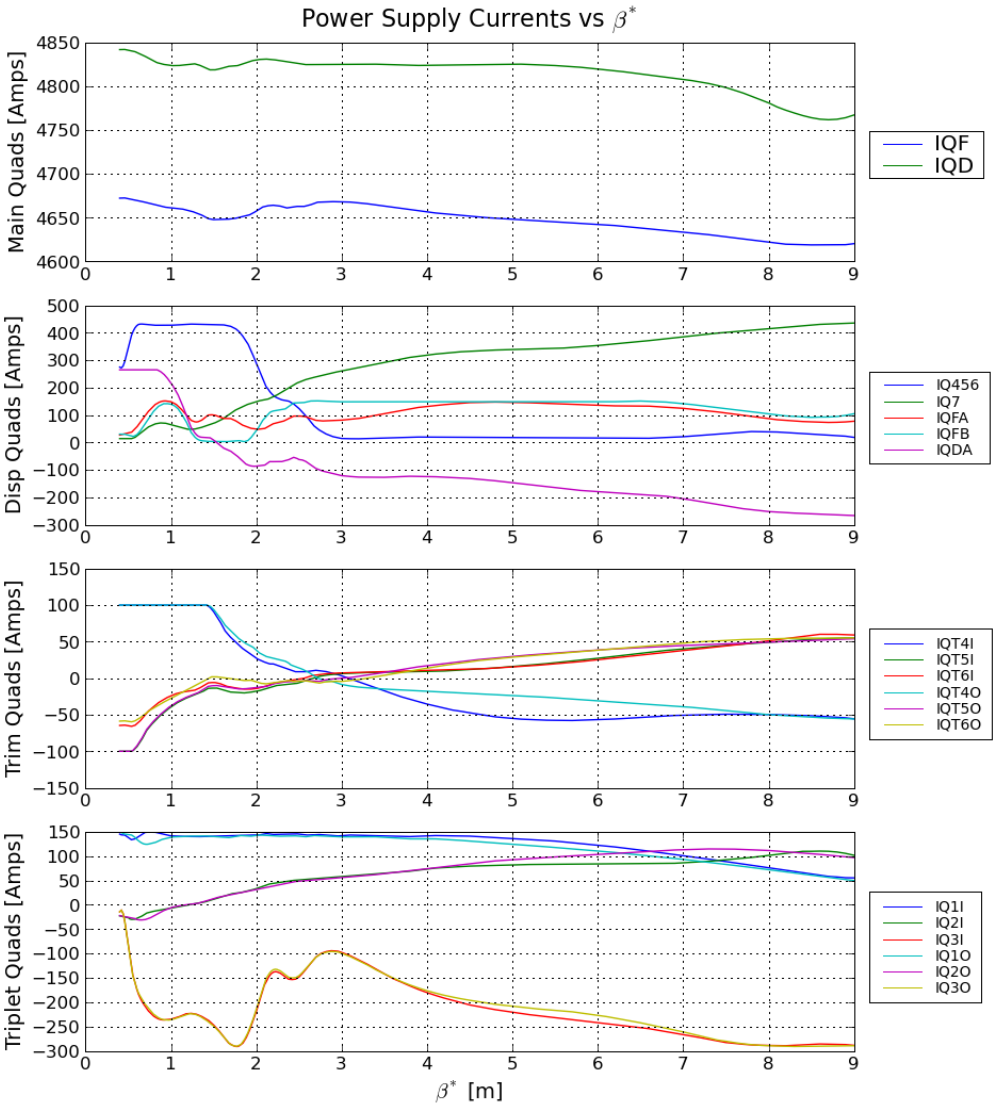
-150
IF
Q7
Q6
Q5
Q4
Q3
Q2
Q1
Q1
Q2
Q3
Q4
Q5
Q6
Q7
IF
200
0
200
0
150
-150
150
-150
300
0
300
0
450
0
600
0
PENETRATION SYMBOLS
6600
2000
150

Low β*

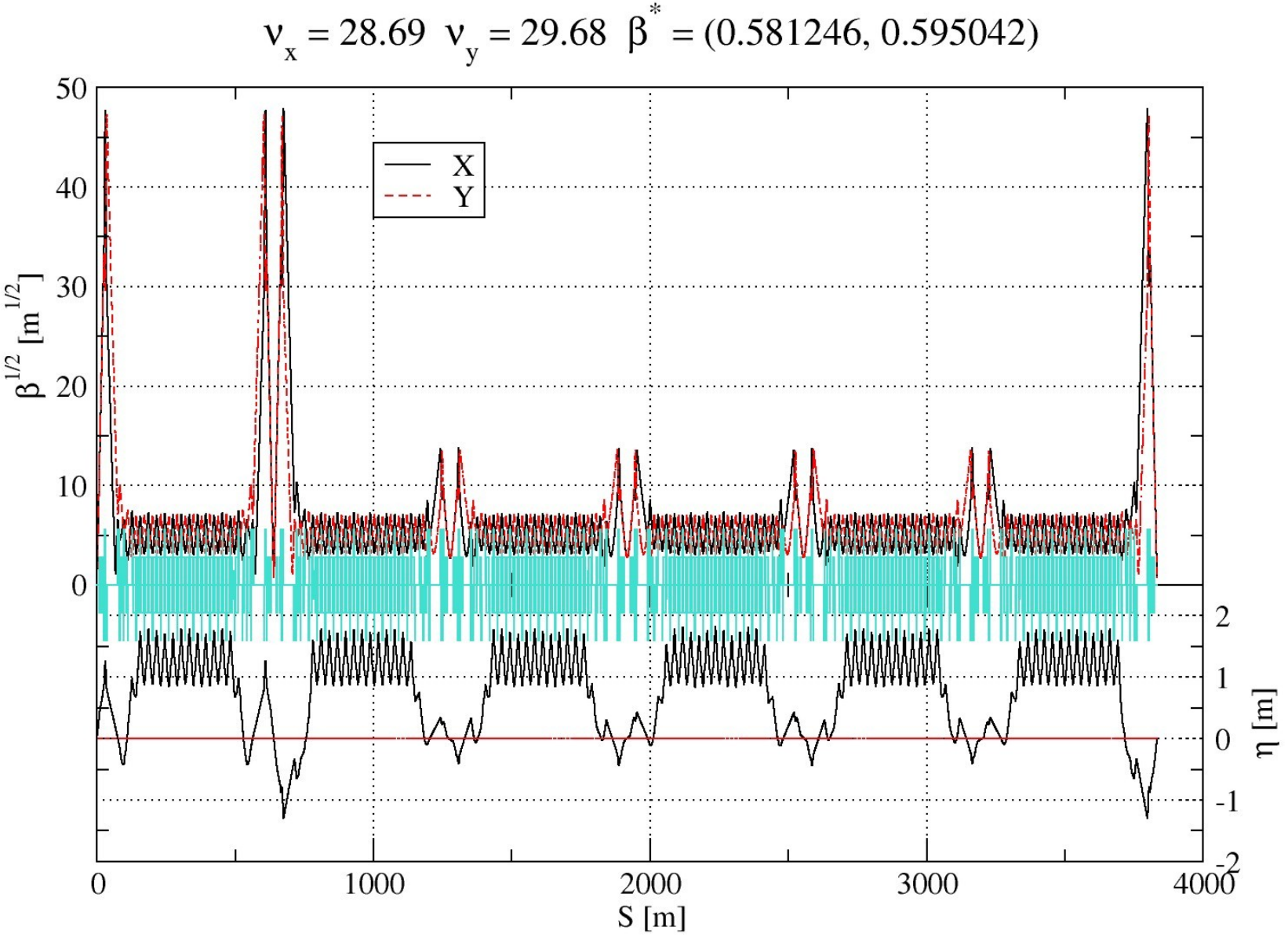
- Fit with existing power supplies
- Try different initial guesses
- Try different weights on the constraints
- Must have a smooth squeeze path from injection
- Fit to lower energy (If possible)
  - 100GeV protons
- Upgrades to IR:
  - Upgrade the power supplies and valve boxes
  - Add new quadrupoles

Low β*

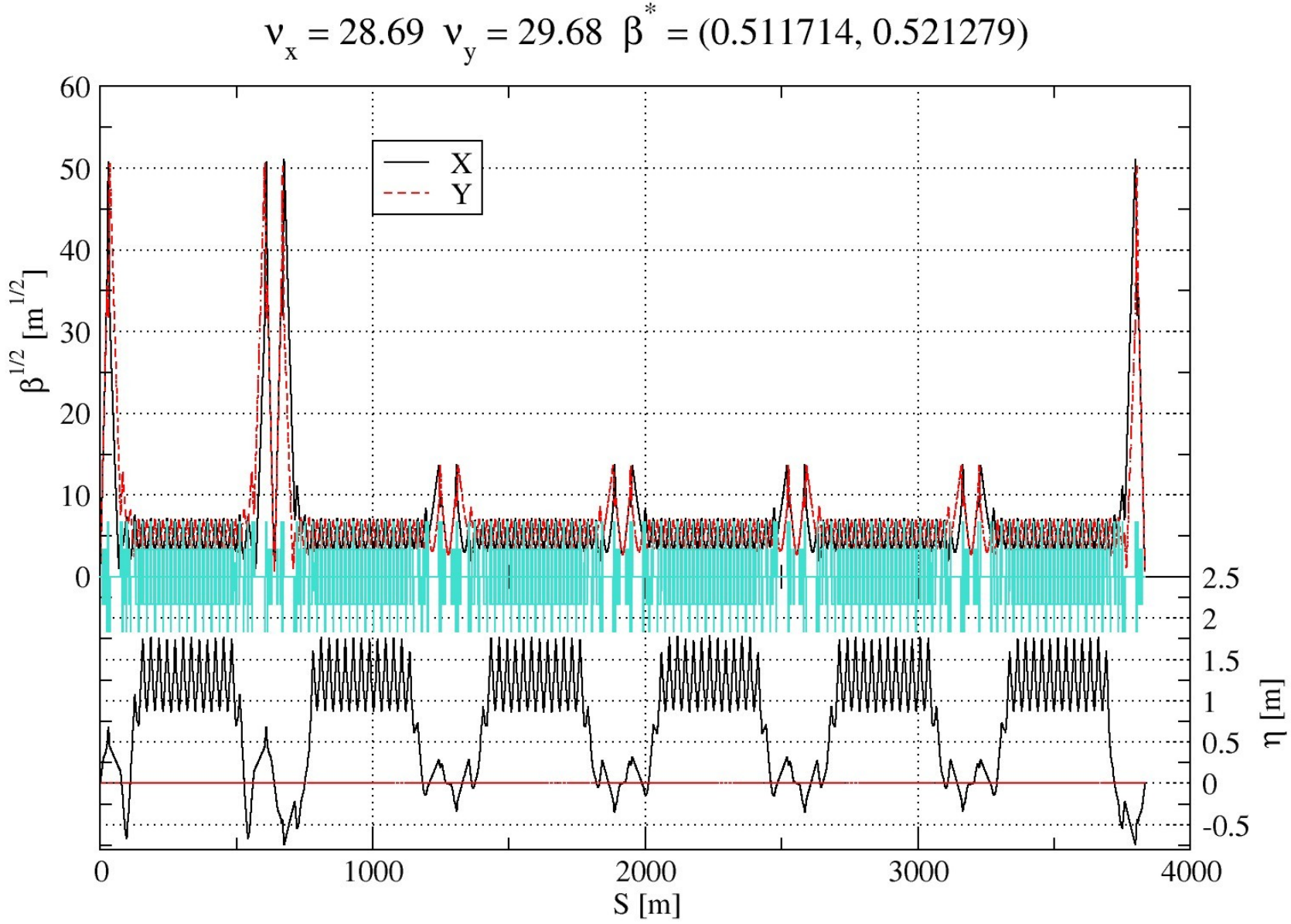
- 250GeV protons
- Some power supplies are hitting limits:
  - PSQ456
  - PSQDA
  - Trim quads:
    - PSQT4I, PSQT4O
    - PSQT5I, PSQT5O



250GeV Blue Ring



100GeV Blue Ring

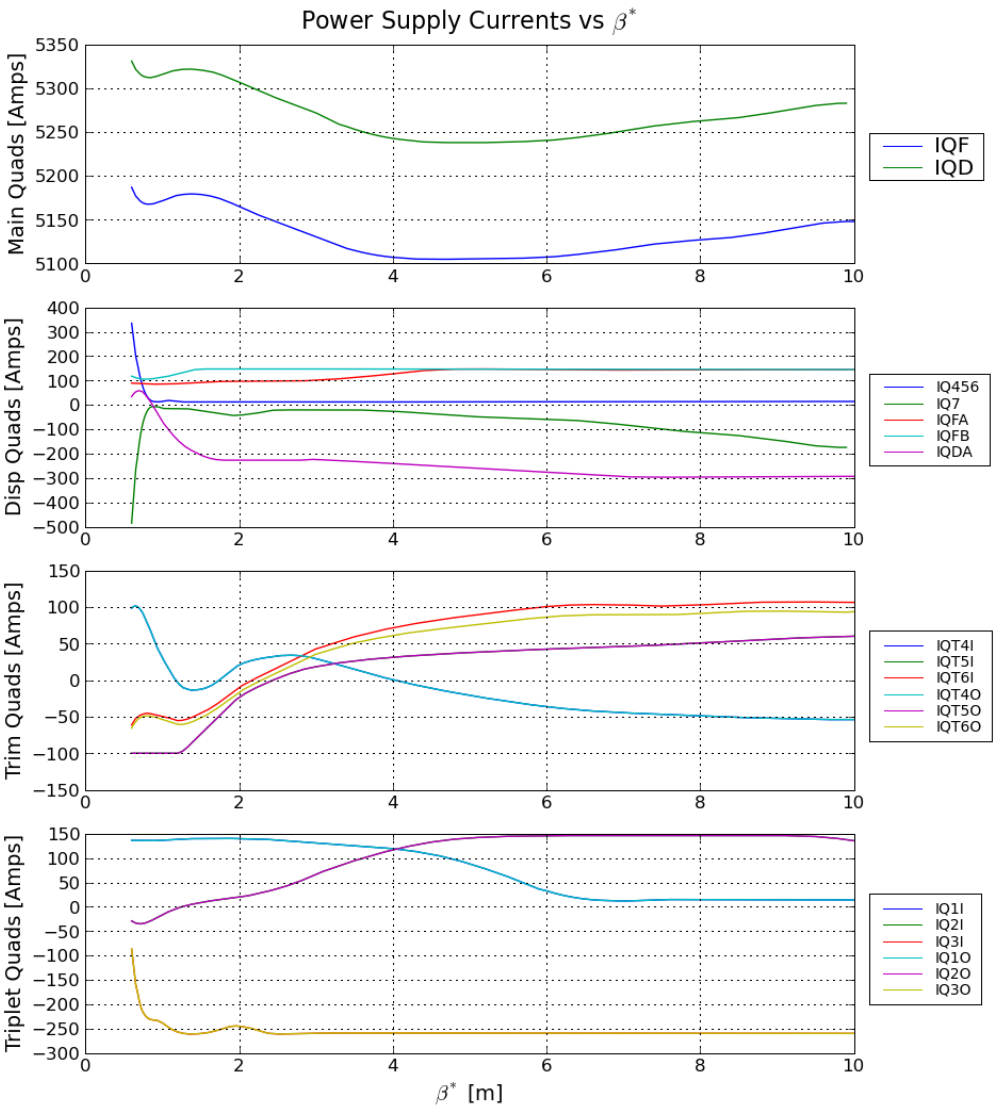


IBS-Suppression Optics

- Raise the tune by +3 units in both planes
  - Tune is adjusted with arc FODO cells
  - Different arc FODO cell to match to the IR
  - Different dispersion for the dispersion suppressor
- Try different initial guess for the IR quadrupoles
- Power supply currents are quite different
- $\beta^* = 0.5m$ is achievable without upgrades to power supplies or additional quadrupoles

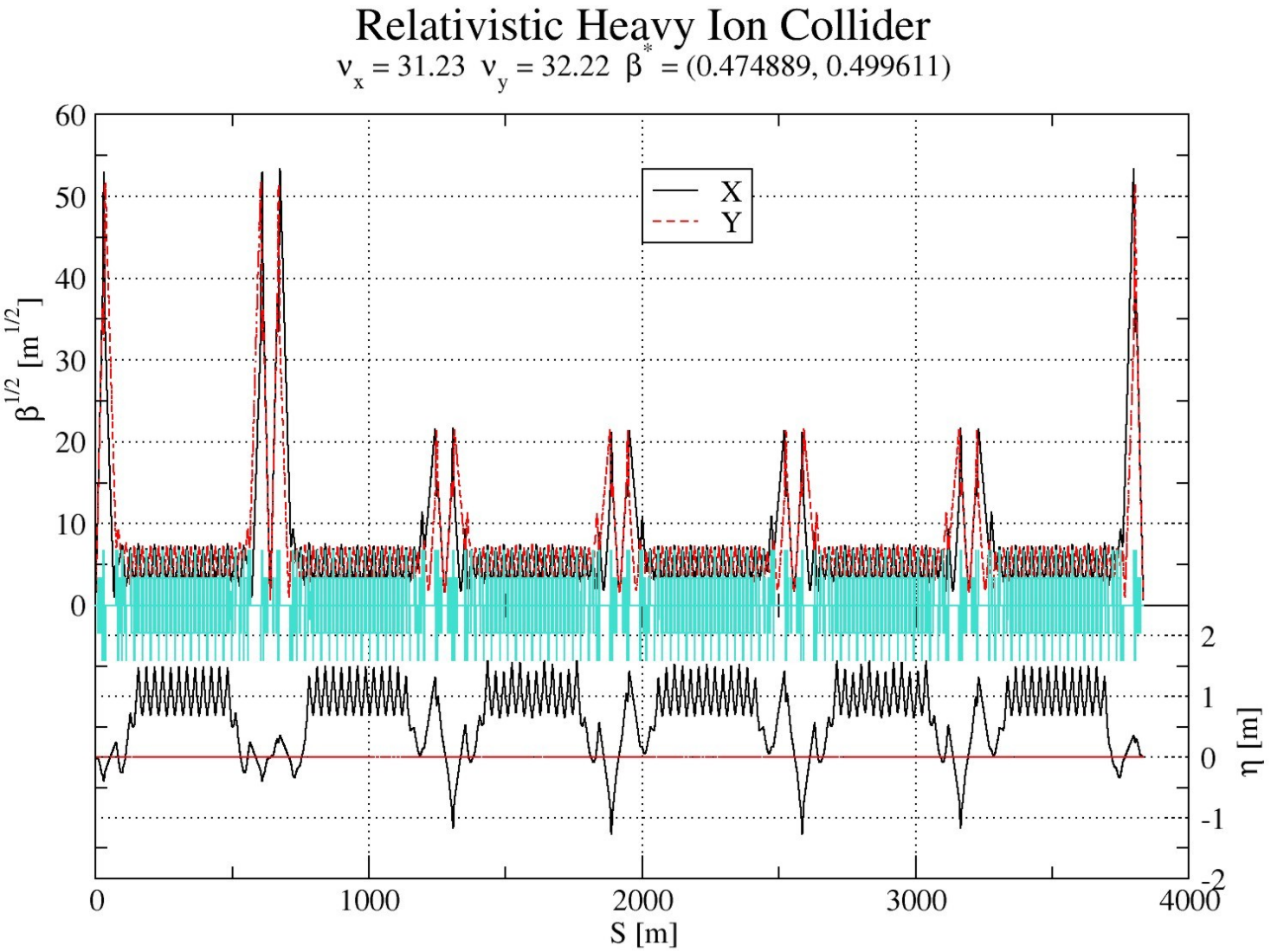
IBS-Suppression Optics

- Run-8: Gold at 100GeV/nucleon
- PSQ7 is reversed
- Trims hit limits
  - PSQT4I and PSQT4O
  - PSQT5I and PSQT5O
- Limits at large β*
  - PSQDA
  - Poor dispersion matching



IBS-suppression Optics

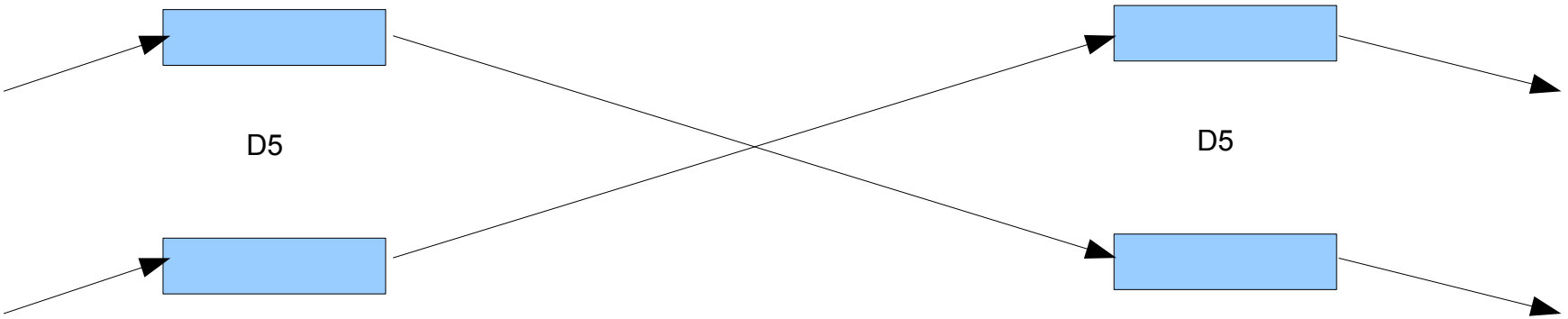
Set expected limits for the trim quadrupole power supplies (150Amps) and Q89 bipolar power supplies (±290Amps)



eCooling Optics

- eCooling IR requirements
  - Large β^* ($\geq 200m$)
  - Minimize dispersion across the free space (η and η')
  - Minimum of $60m$ free space required
- Matching the end of the insertion to the arcs
  - Each RHIC IR can be treated independently
- Requires sufficient parameters (quadrupole strengths) to vary
- Optics are Anti-symmetric

eCooling Optics

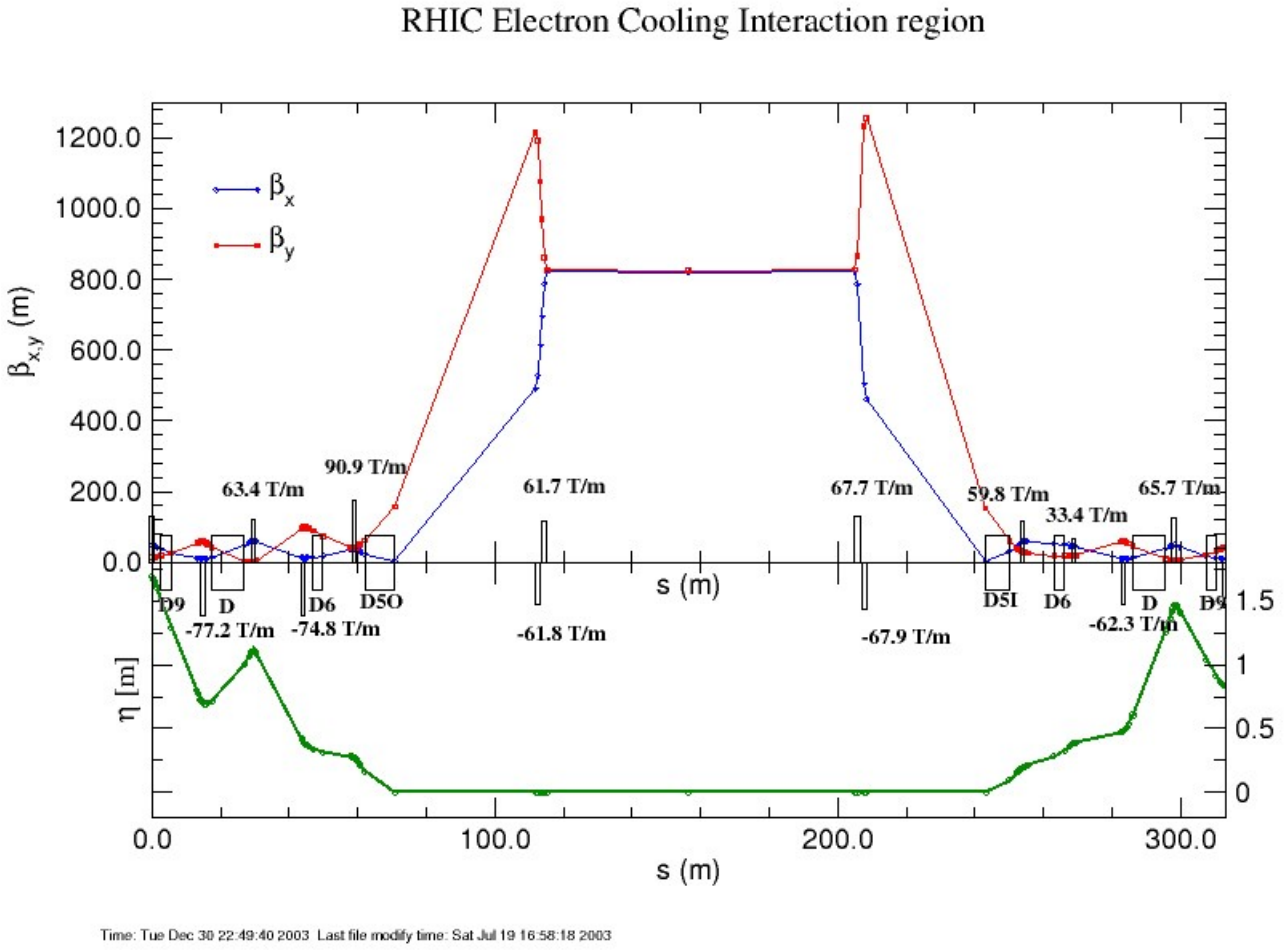


- To get the large free space required the crossing dipoles are removed
- Circumference shorter by 1.996*mm*
- Crossing angle: ~10*mrad*

eCooling Optics

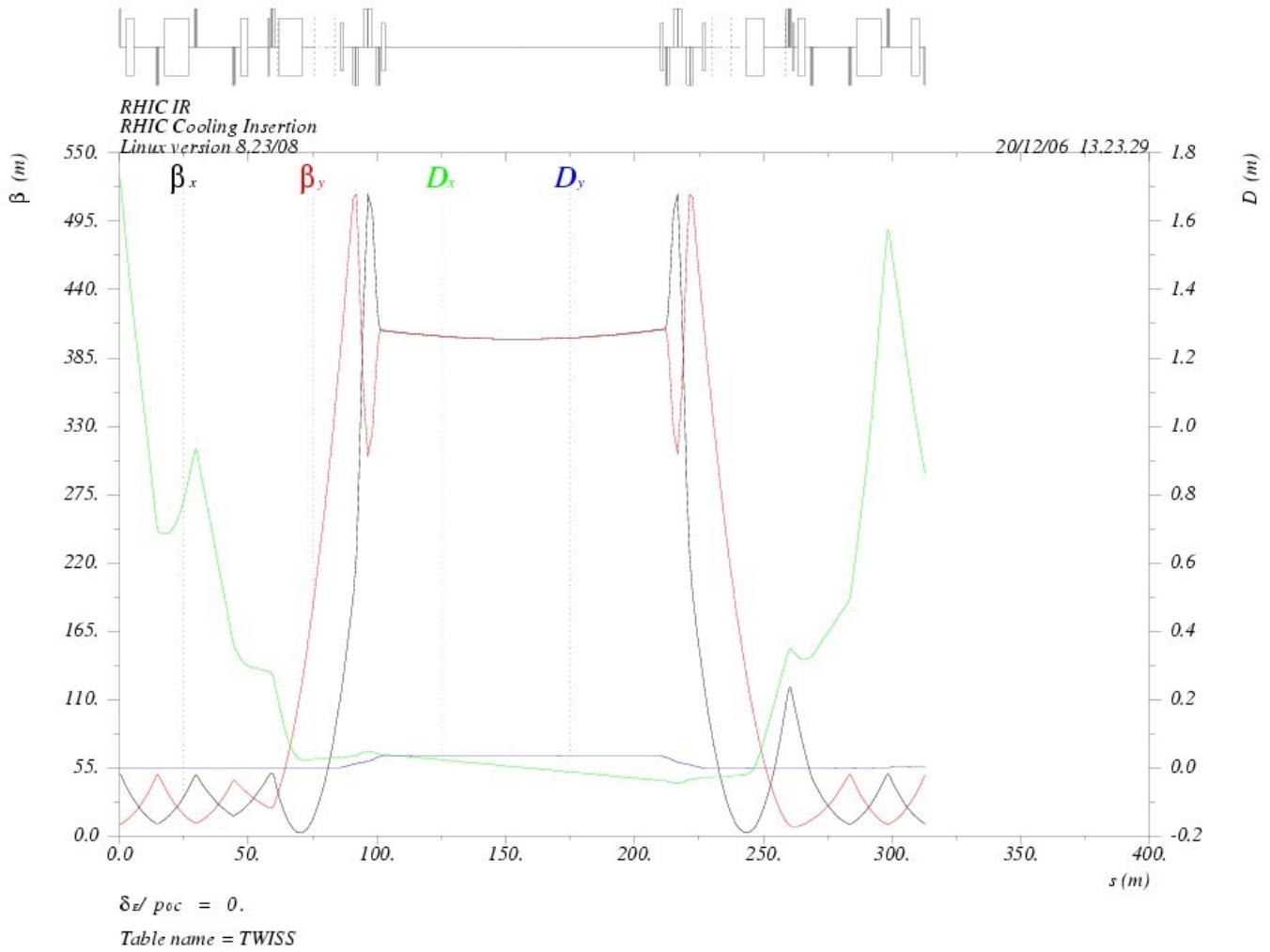
D. Trbojevic

- Symmetric doublets
- Currents in the quadrupoles exceed power supplies
- Large $\beta^* \approx 800m$ and $80m$ *free space*



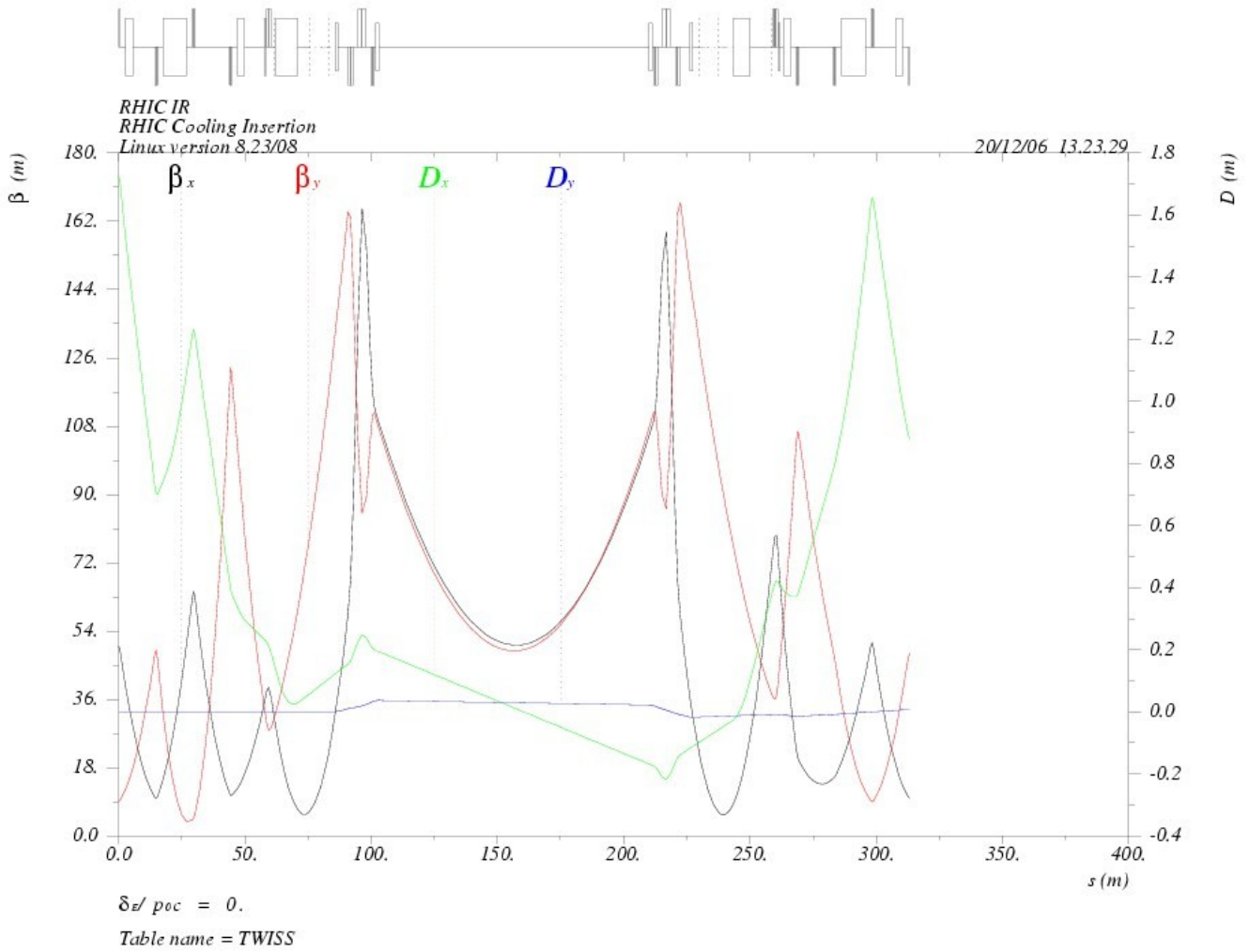
eCooling Optics

- Large $\beta^{*} \approx 400m$ and 110*m free space*
- Includes vertical dispersion due to vertical separation
- Injection acceptance?

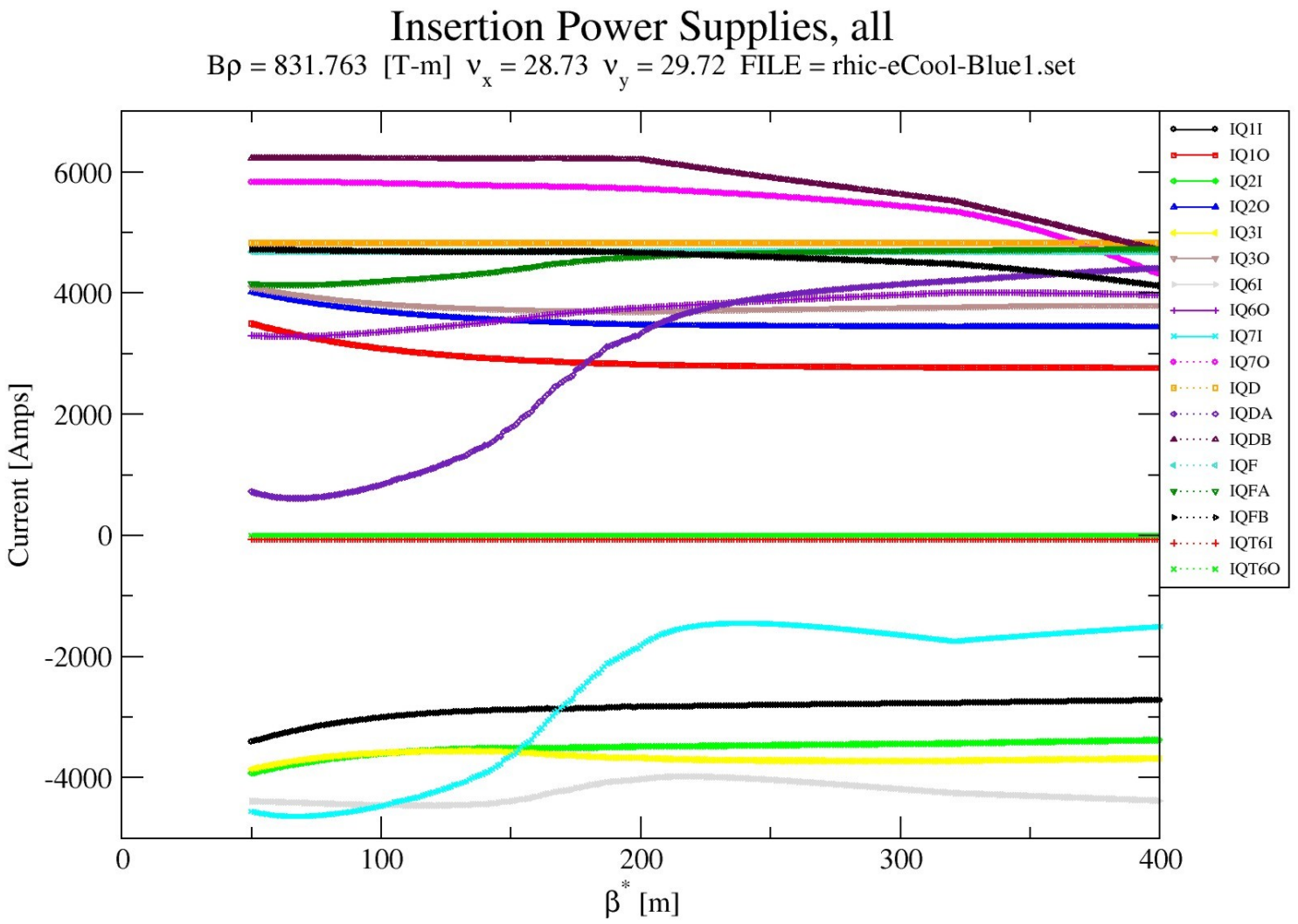


eCooling Optics

- Large $\beta^* \approx 50m$
- Small enough acceptance for injection.

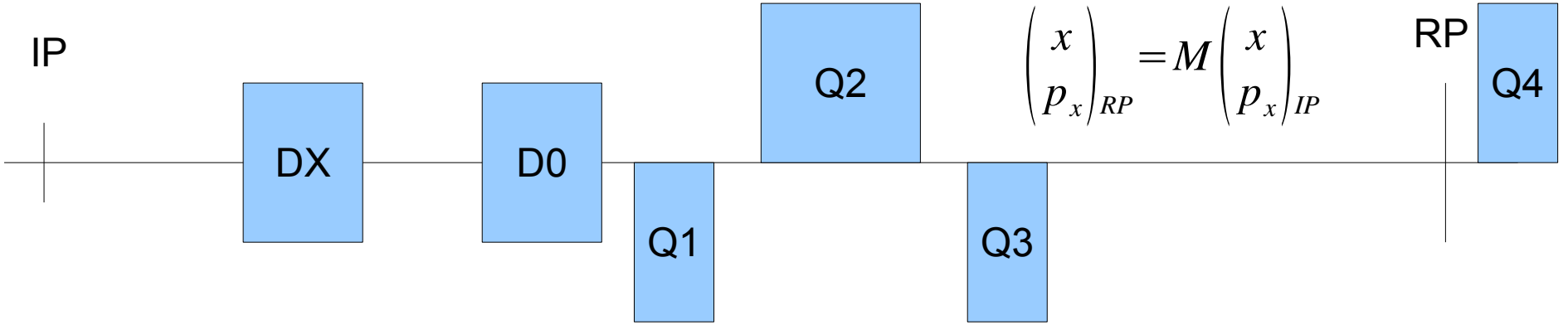


eCooling Optics



pp2pp

PP2PP – Coulomb (Elastic) scattering experiment

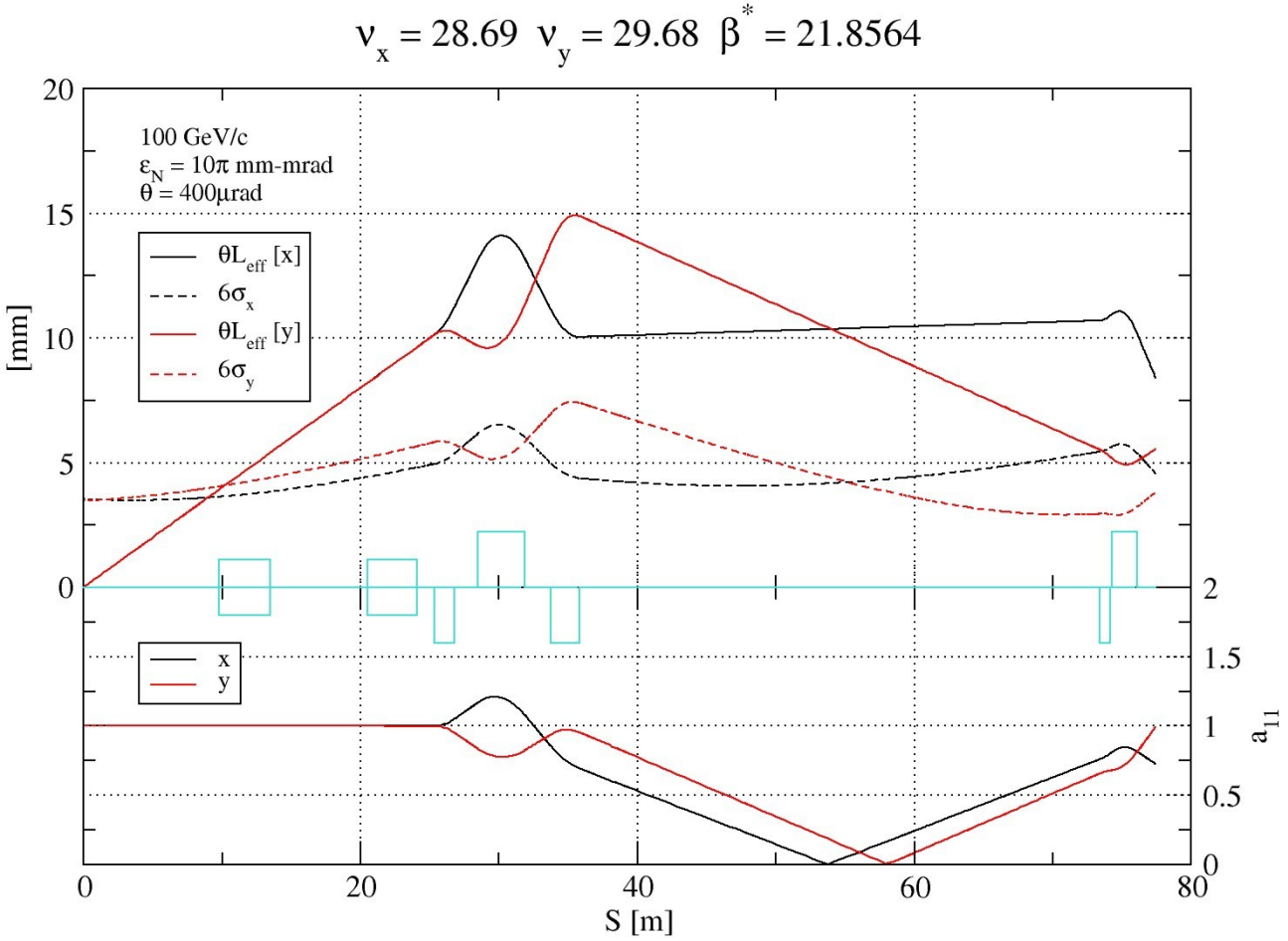


$$M = \begin{bmatrix} a_{11} & L_{eff} \\ a_{21} & a_{22} \end{bmatrix} = \begin{bmatrix} \sqrt{\frac{\beta_{RP}}{\beta_{IP}}}\left(\cos(\Psi) + \alpha_{IP}\sin(\Psi)\right) & \sqrt{\beta_{IP}\beta_{RP}}\sin(\Psi) \\ \frac{\left(1+\alpha_{IP}\alpha_{RP}\right)\sin(\Psi) + \left(\alpha_{IP}-\alpha_{RP}\right)\cos(\Psi)}{\sqrt{\beta_{IP}\beta_{RP}}} & \sqrt{\frac{\beta_{IP}}{\beta_{RP}}}\left(\cos(\Psi) - \alpha_{RP}\sin(\Psi)\right) \end{bmatrix}$$

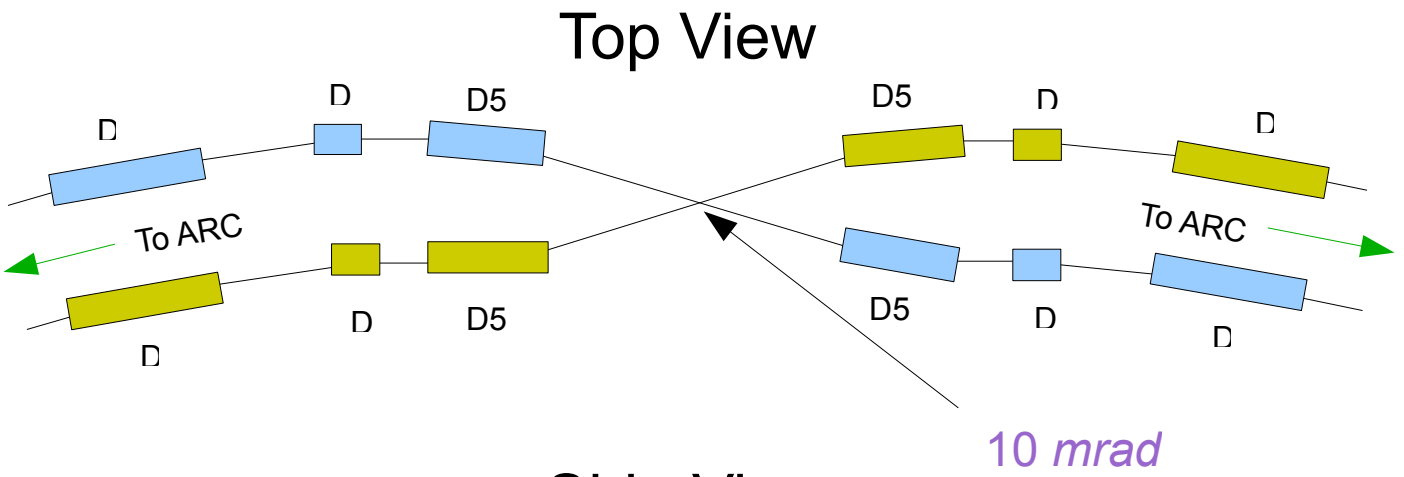
$$a_{11} \approx 0 \quad \Rightarrow \quad \Psi = \frac{\pi}{2} \quad \Rightarrow \quad L_{eff} = \sqrt{\beta_{IP}\beta_{RP}}$$

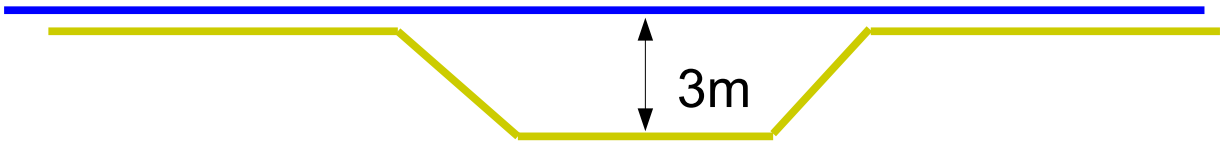
pp2pp

- 100GeV PP2PP
- Roman Pots
  - Hor – 55.5m
  - Vert – 58.5m
  - 12 ~ 15σ from beam center
- L_{eff}
  - Hor ~ 26m
  - Vert ~ 23m



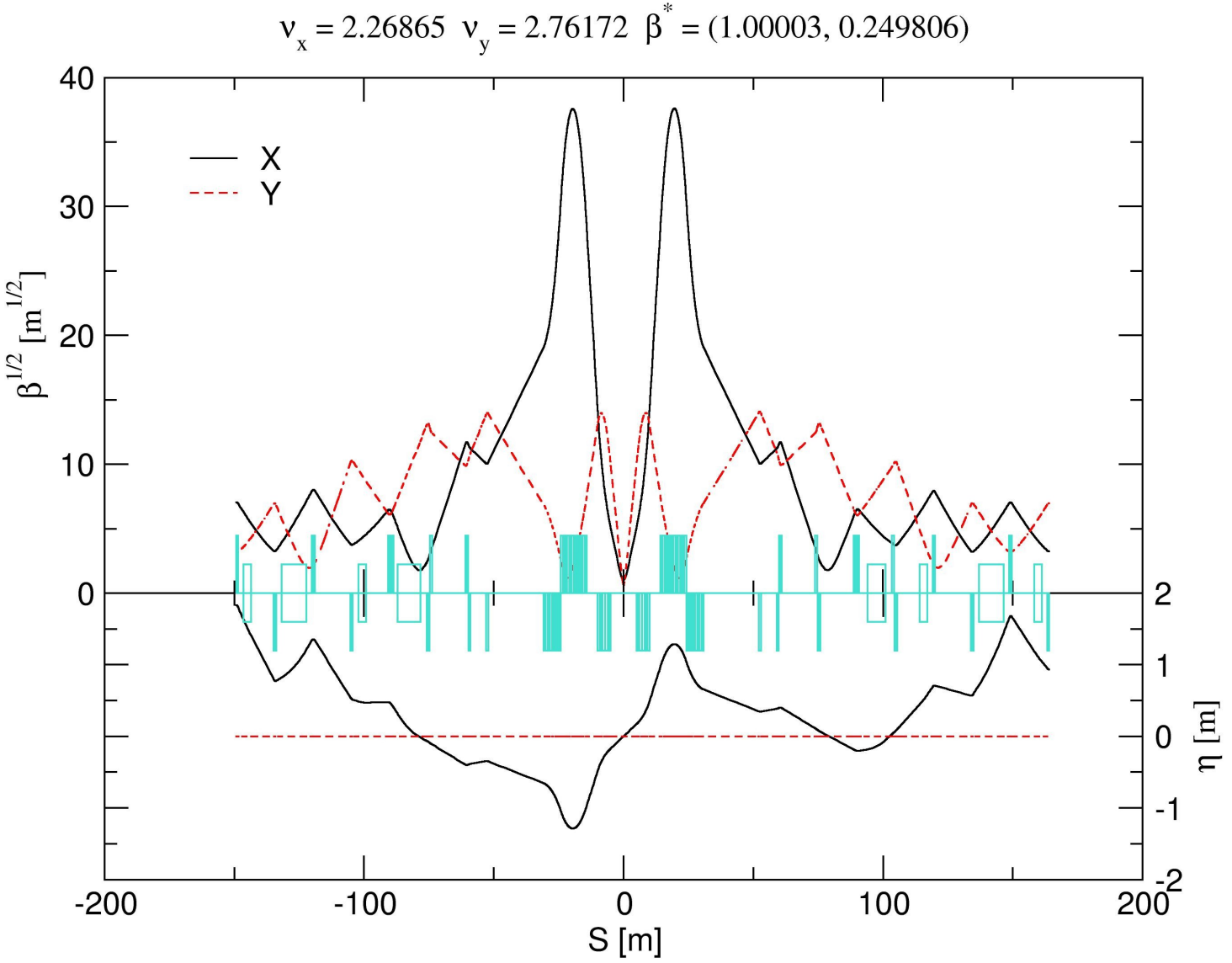
eRHIC





Circumference difference between the rings: 15.8*cm*

Blue ring optics from Release 2.0



Yellow IR optics with vertical bends